PROPERTIES OF BITUMINOUS MIXES USING INDONESIAN NATURAL ROCK ASPHALT

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ABSTRACT

Indonesian natural rock asphalt is known as Asbuton i.e. Rock asphalt from Buton Island containing bitumen content 5% to 30%.
Granular type of Asbuton product are available as known as Buton Granular Asphalt (BGA). Research and development has been ongoing, to obtained better quality asbuton product.
The aim of this study, is to investigate the properties of bituminous mixes using asbuton product. The laboratory result proves that the mixes using added BGA and petroleum bitumen increases some test properties and decreases others, compare to properties of mixes using only petroleum bitumen or pure refinery asbuton bitumen.
Mixes containing blend of BGA and petroleum bitumen are less temperature susceptible and will improve resistance of a mix to permanent deformation and also will improve the load spreading ability.
On the other hand, mixes containing blend of BGA and petroleum bitumen will be detrimental to cohesiveness and stripping and also fatigue life in term of initial strain level compare to mixes using petroleum bitumen or pure refinery asbuton bitumen.
Due to the complexity of bituminous mixture, performance may not be predicted by a single variable. Therefore, it is necessary to examine the connection between mix variables to determine optimum properties.

Key words : Asbuton, Buton Granular Asphalt, pure refinery asbuton bitumen, petroleum bitumen, permanent deformation, cohesiveness, fatigue,.

1. INTRODUCTION

Indonesia currently consumes 1.2 million tonnes of bitumen annually for maintaining and constructing new roads. About 600,000 tonnes are locally produced and the rest is imported. The local product consist of 500,000 tonnes of petroleum bitumen and 100,000 tonnes of natural rock asphalt in granular form.
The natural rock asphalt deposits in Indonesia are found on South Buton Island in southeast Sulawesi island known as Asbuton, abbreviation of Asphalt Batu Buton i.e. Rock asphalt from Buton Island, as shown in Figure 1.
There is a large reserve of natural rock asphalt in Indonesia containing a bitumen content of 5% to 30% with an average bitumen content of 20% and bitumen properties as low as 0 to 10 dmm in Kabungka area and as high as 60 to 210 dmm in Lawele area. The size of deposit has been variously estimated at up to 200 million tonnes. The deposit is therefore an important national resource with the potential to reduce the need of imported bitumen and generate export income
The best known of the Asbuton deposits are those of the Kabungka and Lawele area. These are collectively known as Asbuton deposits.
The fact that a range of bitumen treatment options are required to produce a consistent product is a major consideration in the overall refining strategy and economics of these deposits.

Figure 1. Location of map for Buton Island deposits

2. DEVELOPMENT OF INDONESIA NATURAL ROCK ASPHALT PRODUCT

Asbuton as natural rock asphalt consists of a granular material usually limestone or sandstone. In it natural state its contains bitumen intimately dispersed throughout its mass, the remainder of the material is solid mineral matter, as shown in Figure 2 and Figure 3.

Figure 2. Natural state of bitumen asbuton

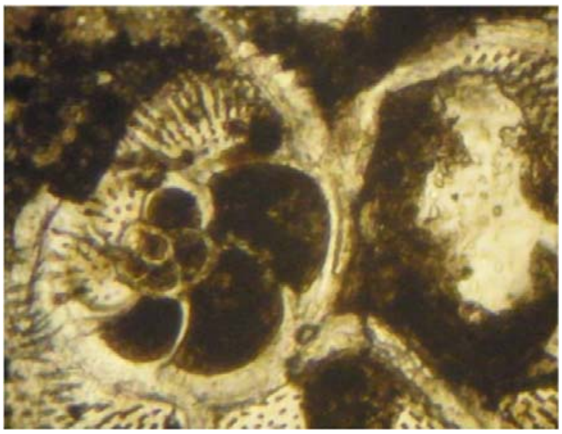

Figure 3. Bitumen and mineral in asbuton

In the past, only granular types of Asbuton product were available in the market. These products were produced by crushing and the size varies from 12.5 mm (conventional asbuton) down to less than 0.6 mm (Mikro Asbuton). The product can be applied either in a cold mix by fluxing the Asbuton with a suitable rejuvenating flux oil or in a hot mix system through the formation of a hot mastic. To obtain a better quality Asbuton product, research and development has been ongoing. In the present, granular type of Asbuton product has the maximum size 1.16 mm as known as Buton Granular Asphalt (BGA) and also a viable refining process has been developed. The refining process reduces the mineral content to produce pure refinery asbuton bitumen that has a bitumen content nearly 100% (pure refinery asbuton bitumen - PRAB).

Buton Granular Asphalt (BGA) has the maximum particle size of 1.16 mm which are homogenised, finely ground and limitation of water content. BGA consist of two types, first is “5/20 BGA” with penetration bitumen < 10 dmm and bitumen content between 18 – 22 %, meanwhile the second one is “20/25 BGA” where its penetration bitumen between 19 – 22 dmm and bitumen content 23 to 27 %.

3. THE RHEOLOGICAL PROPERTIES OF BITUMEN

Bitumen is only a minor component of bituminous mixes. But it has a crucial part to play in providing visco – elasticity and acting a durable binder. Essentially, the performance of a binder is achieved if certain properties are controlled, namely rheology, cohesion, adhesion and durability. The primary or routine rheological properties are penetration, softening point and viscosity.
The temperature susceptibility is usually described as the change of primary or routine rheological properties of bitumen with temperature.
Pleiffer and Van Dormaal defined the temperature susceptibility of bitumen as the Penetration Index

$$PI = \frac{1952 - 500\log Pen - 20(SP)}{50\log Pen - (SP) - 120} \quad \text{.............................} (1)$$

Where : pen = penetration
SP = Softening Point

The value of PI ranges from -3 for highly temperature susceptible bitumens to about + 7 for highly blown low temperature susceptible (high PI) bitumen.
The physical properties of BGA, pure refined asbuton and pure petroleum bitumen 60/70 pen grade and in this research are shown in Table 1.

Table 1 Rheology properties of bitumen BGA, Pure refined asbuton product and pure petroleum bitumen 60/70 pen grade

No	Property	Bitumen of BGA	Pure Refined Asbuton Bitumen	Pure Petroleum bitumen 60/70 pen grade (PPB)	Unit
1	Penetration at 25 C	9	83	62	0.1 mm
2	Softening Point (R& B)	-	48.8	51.4	^{o}C
3	Ductility	-	> 140	> 140	Cm
4	Solubility in C_2HCL_3	-	98.7	99.6	%
5	Flash Point	-	-	325	^{o}C
6	Unit Weight	-	1.06	1.04	-
7	Loss on Heating TFOT		1.8109	0.011	%
8	Penetration after loss on heating	-	50	50.8	0.1 mm
9	Softening Point after loss on heating	-	53.7	49.5	^{o}C
10	Ductility after los on heating (TFOT)	-	> 140	> 140	Cm
11	Bitumen content	23			%

This Table showed that the bitumen content of bitumen from BGA is 23% and its bitumen is quite hard as indicated by penetration value just only 9 dmm and pure refined bitumen asbuton is quite soft as indicated by penetration value 83 dmm.
Based on the data in Table 1 and using equation (1), the Penetration Index (PI) of Pure Refined Asbuton Bitumen is – 0.236 and pure petroleum bitumen 60/70 pen grade is -0.246, where both of these bitumen have medium temperature susceptibility.

4. BITUMINOUS MIXTURES

The type of bituminous mixes selected is Asphaltic Concrete (AC), because Asphaltic Concrete mixes has performed well and is commonly used in Indonesia. Asphaltic Concrete mixes are continuously graded mixtures of aggregate, filler and bituminous binder.
The bitumen content for a particular blend or gradation is determined using the Marshall method. A series of test specimens are prepared for a range of bitumen contents so that the test data curves

show well defined relationships. Three test specimens are prepared for each bitumen content. The aggregate grading for Indonesia Asphalt Concrete is shown in Table 2 and Figure 4.

Table 2. Aggregate grading for Indonesia Asphaltic Concrete and grading of the mixes

Sieve size (mm)	Percent mass passing		
	Specification grading Wearing course	Grading of the mixes using PRAB 60/70 pen grade and mixes using PB	Grading of the mixes using added BGA
25	-	-	-
19	100	100	100
12.5	90 – 100	90.8	90.2
9.5	Max 90	82.6	81.5
4.75	-	53	50.5
2.36	28 – 58	36.6	35.4
1.18	-	24.7	25.1
0.600	-	16.9	18.3
0.300	-	11.9	13.2
0.075	4 – 10	5.9	7.3
Restricted zone			
4.75	-		
2.36	39.1		
1.18	25.6 – 31.6		
0.600	19.1- 23.1		
0.300	15.5		

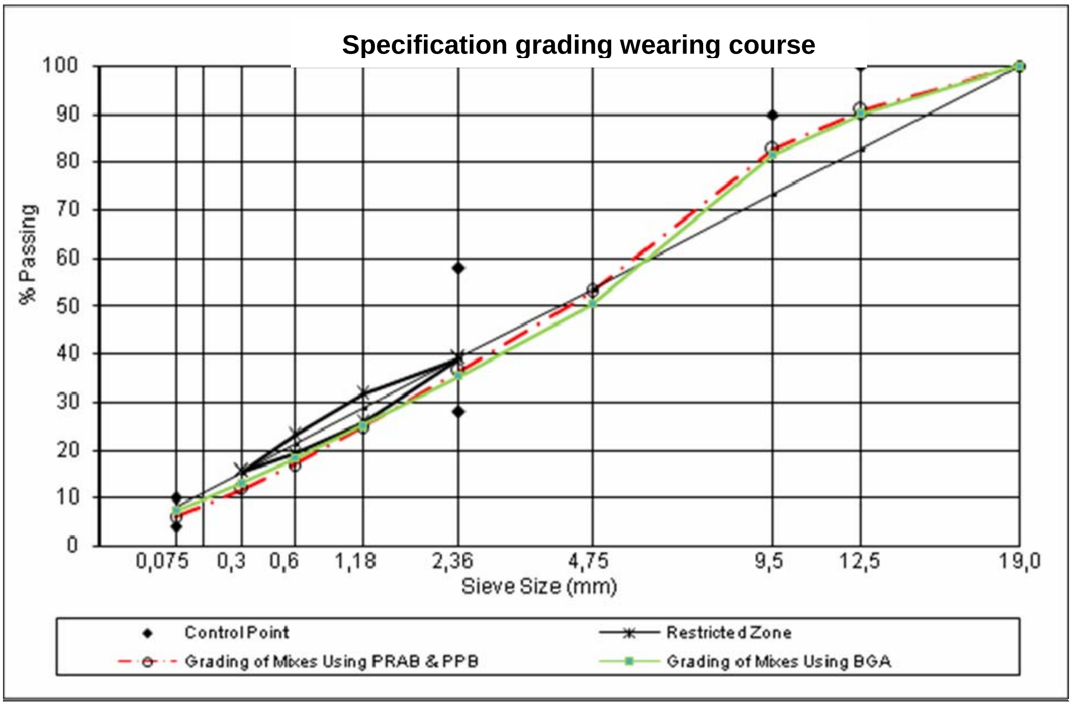

Figure 4. Chart of specification grading for Indonesia asphalt Concrete and grading of the mixes

The design bitumen content is selected by considering all of the data properties of the mix. The calculated and measured mix properties at this bitumen content can be evaluated by comparing them to the mix design criteria shown in Table 3. The design bitumen content is a compromise selected to balance all of the mix properties and can be adjusted within the range to achieve properties that will satisfy a requirement for a specific project. Optimum bitumen content of mixes added BGA, using PRAB and mixes using pure petroleum bitumen 60/70 pen grade (PPB) are 6.25%, 6.1% and 6.1 % respectively.

Table 3. Mix Design Criteria of Indonesia Asphaltic Concrete

Mix Criteria		Asphaltic Concrete	Asphaltic concrete modified
		Wearing Course	Wearing course
Number of compaction blows	-	2 x 75	2 x 75
Void in Mix (VIM) (%)	Min	3.5	3.5
	Max	5.5	5.5
Void in Mineral Aggregate (VMA) (%)	Min	15	15
Void Filled Bitumen (%)	Min	65	65
Marshall Stability (kg)	Min	800	1000
Flow (mm)	Min	3	3
Marshall Quotient (kg/mm)	Min	250	300
Retain Marshall Stability (%)	Min	80	80
VIM (%) at refusal density	Min	2.5	2.5
Dynamic Stability (pass/mm)	min		2500

Sources : Department of Public Works Indonesia (2007).

4.1 The Stiffness Modulus of Bituminous mixes

The stiffness Modulus of a bituminous mix is the ratio between stress and strain. It is perhaps the most important fundamental mix property as it provides information on how the material will deform under the action of a given load. This is related to load spreading ability.
The higher the stiffness of pavement the better the load spreading onto the sub grade. The load spreading principle in a pavement is illustrated in Figure 5.
The Stiffness Modulus of a bituminous mixture (S_m) is dependent on both temperature and on the speed with which the stress is applied. The stiffness of the mixture will vary as the stiffness modulus of the bitumen changes.

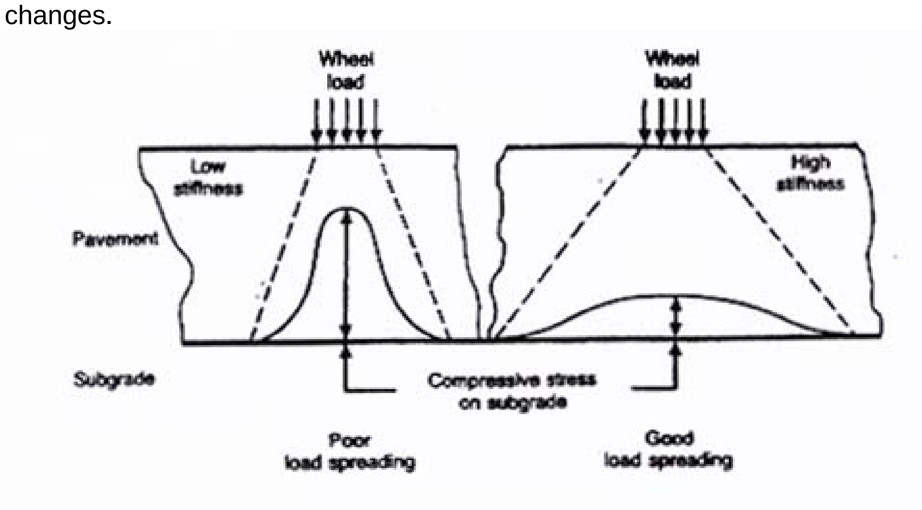

Figure 5. Spread loading in a road pavement (Brown, 1994)

4.1.1 Measurement of Stiffness Modulus of Bituminous Mixes

The test specimens for this test was prepared in the laboratory as for the Marshall test at each optimum bitumen content, each had diameter of 100 mm and thickness of 62.5 mm.
The method used was the Indirect Tensile Stiffness Modulus using the Universal Machine Testing Apparatus equipment. The stiffness test was used at the standard test temperature 25 ^oC; 35 ^oC; 45 ^oC and 55 ^oC with an axial stress of 200 kPa. The specimens were conditioned at the test temperature for one night. The test was carried out in a cabinet with forced air circulation.
The principle of the test, is that a cylindrical specimens is subjected to a compressive load pulse along one diameter which results in an indirect tensile stress along the diameter lying at right angles to the direction of the load. The transient deformation due to indirect tensile strain is measured. Elastic stiffness is a function of the measured compressive load and transient tensile deformation.
A sequence of five conditioning load pulses are applied to the specimen followed by five loading pulses.

4.1.2 Stiffness Modulus of Asphaltic Concrete Mixes

The mean value of Stiffness Modulus for each mixes added BGA 5%,mixes using PRAB and mixes using PPB is shown in Table 4 and plotted in Figure 6. In all cases the stiffness modulus for AC mixes decreased as the temperature of test increased as shown in Figure 6.

In Figure 6. it can be seen that the Stiffness Modulus of mixes added BGA had the greatest Stiffness Modulus, and were followed by the same mix using PPB and mixes using PRAB for any test temperature.

Table 4. Stiffness Modulus of mixes using blend of BGA and petroleum bitumen; Pure Refined Asbuton Bitumen bitumen 60/70 pen grade (PRAB) and pure petroleum bitumen (PPB).

Test Temperature (ºC)	Stiffness Kg/cm² (MPa)		
	Mixes added BGA	Mixes using PRAB	Mixes using PPB
25	56357 (5419)	25136 (2417)	30687 (2950)
35	22263 (2140)	10781 (1036)	11086 (1066)
45	11700 (1125)	5520 (530)	3861 (371)
55	6058 (582)	3086 (296)	2397 (230)

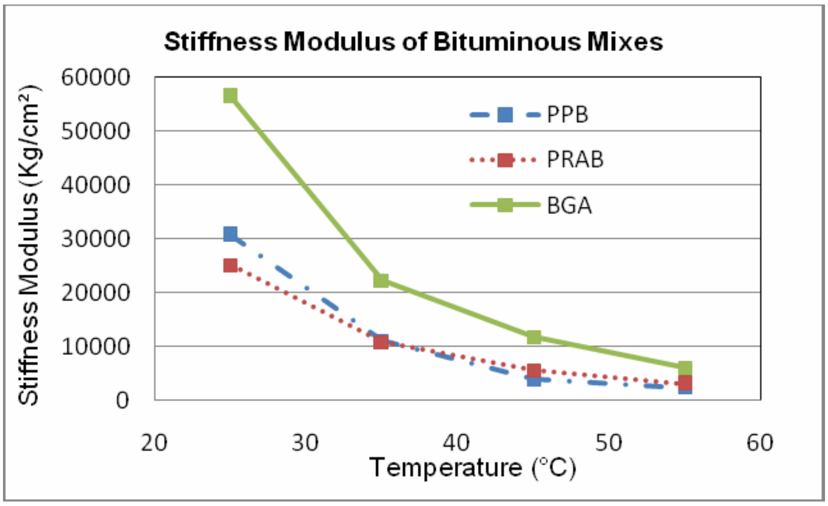

Figure 6. Plot of Stiffness Modulus and test temperature for mixes added BGA , mixes using PRAB, and mixes using PPB

4.2 Permanent Deformation of Bituminous Materials

When a bituminous mixture is subjected to a brief application of load the material will deform. When the load is removed a large part of this deformation is recoverable. However, there will be small irrecoverable permanent deformation. If the bituminous mixture is subjected to a series of load applications there will be an accumulation of permanent deformation.

The deformation behaviour of a mix depends on temperature. The higher the temperature the greater the deformation for the same loading time. The influence of temperature change affects bitumen stiffness and so changes stiffness of the mix.

4.2.1 Method of Assessing Resistance of Bituminous Materials to Permanent Deformation

A simulative test for evaluating the resistance to permanent deformation is the wheel tracking test. This test has been used to compare the performance of different materials rather than predict in situ performance.

In a laboratory wheel tracking test of the specimen is subjected to a test load. They were compacted in a rigid mould using a special steel roller compactor design to simulate the action site compaction. The

specimens tested were in a slab form having dimension of 300 x 300 mm and thickness of 50 mm. The wheel tracking apparatus was located within a constant temperature room. The mounted test specimens were conditioned for 10 hours at the specified test temperature prior to testing. During wheel tracking test, the specimen was confined in the rigid mould and a loaded wheel with the contact pressure of 6.4 ± 0.15 kg/cm2 driven backward and forward at 21 ± 0.2 cycles per minute. The depth of tracking was recorded at the midpoint of the sample length. The test continued for 60 minutes. The temperature of testing of the samples was 60 ºC.
The parameters obtained from the wheel tracking test are the Rate of Deformation and Dynamic Stability :

$$DS = 42\frac{(t_2 - t_1)}{(d_2 - d_1)} \quad \text{...} (2)$$

$$RD = \frac{(d_2 - d_1)}{(t_2 - t_1)} \quad \text{...}(3)$$

Where DS = Dynamic Stability (number of passes/mm)
RD = Rate of Deformation (mm/min)
d_1 = value of deformation at time t_1 time deformation graph
d_2 = value of deformation at time t_2 time deformation graph

Normally t_1 and t_2 are 45 and 60 minutes of deformation graph for the test duration of 60 minutes respectively.

4.2.2. Resistance to permanent deformation of mixes using Wheel Tracking Machine

The deformation obtained for the mixes added BGA, mixes using PRAB and PPB 60/70 pen grade are shown in Figure 7. From Figure 7 it may be seen that the wheel track deformation of mixes added BGA is the smallest followed by mixes using PRAB, and mixes using PPB 60/70 pen grade. This indicates the superiority, in terms of the resistance to permanent deformation, of mixes added BGA 5%. The Dynamic Stability (DS) and Rate of Deformation (RD) for each of the mixes is shown in Table 5 .

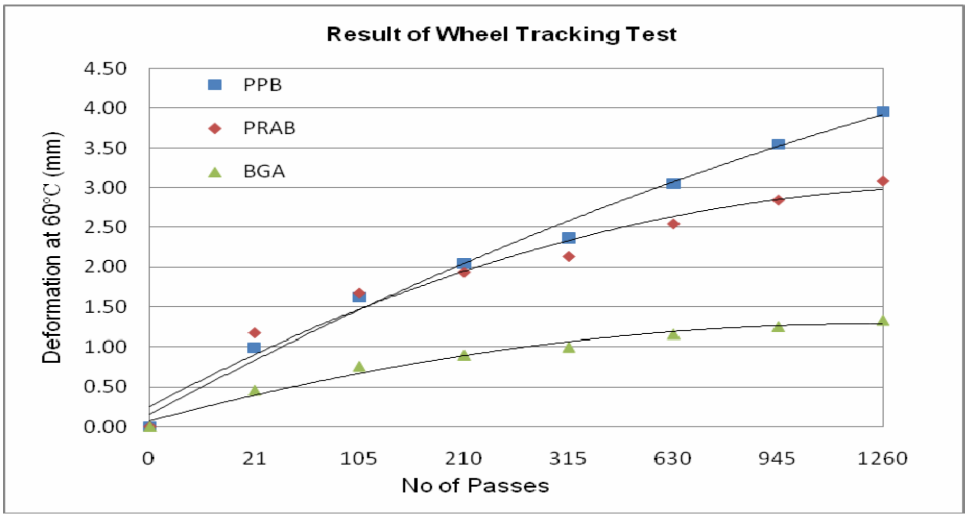

Figure 7. Plot of deformation

Table 5. The Dynamic Stability and rate of deformation of the mixes

Type of mixes	Dynamic Stability (DS)- passes / mm	Rate of deformation (RD) (mm/min)
Mixes added BGA	7875	0.0053
Mixes using PR AB	2625	0.0160
Mixes using PPB	1536.6	0.0273

4.3 Mix Cohesion and resistance to stripping

The resistance to disintegration of bituminous mixes in the laboratory may be assessed using the Cantabro test. Woodside and Woodward reported that the Cantabro test may be used as a simple tool in the laboratory prediction of bituminous mixes performance, because it has ability to rank bituminous materials in relation to expected in – service performance. They concluded that the Cantabro test can be used in a much wider range of applications than assumed.
Two properties can be determined i.e. resistance to disintegration and resistance to stripping. The resistance of a mix to disintegration is the loss experienced for test sample in a dry condition. The loss obtained after a period of immersion in water allows the resistance to stripping by water to be assessed.

Moulds of 100 mm diameter, 63.5 mm height are abraded in a Los Angeles machine. The % mass loss after 300 revolution turns is termed the Dry Particle Loss (PLd) . For measuring water sensitivity a further moulds are soaked in water for 68 hours followed by 24 hours in an oven at 25 C. These are subjected to 300 turns and the % loss is given as the Wet Particle loss (PLw). Particle Loss Index (PLI) may be calculated as :

$$PLI = 100 \times PLw / PLd \quad \text{..........................} \quad (4)$$

The specimens for Cantabro test in this research were prepared for AC mixes added BGA, mixes using PRAB and mixes using PPB 60/70 pen grade at each optimum bitumen content in the mixes. Each mould was weighed prior to testing, the number of revolutions were extended to 500 instead of 300 to increase the amount of disintegration. The percentage loss was calculated every 50 revolutions so that the trend of disintegration could be better determined.
The data obtained for those AC mixes are plotted in Figure 8. It can be seen from Figure 8, that the dry particle loss (PLd) and wet particle loss (PLw)of mixes added BGA is the highest the percentage mass loss, followed by mixes using PPB and mixes using PRAB. Dry particle loss of mixes added BGA, mixes using PPB and mixes using PRAB are 6.5%, 5.7% and 3.4% respectively, mean while wet particle loss (PLw) are 7.4%, 7.2%, 7.1% respectively.

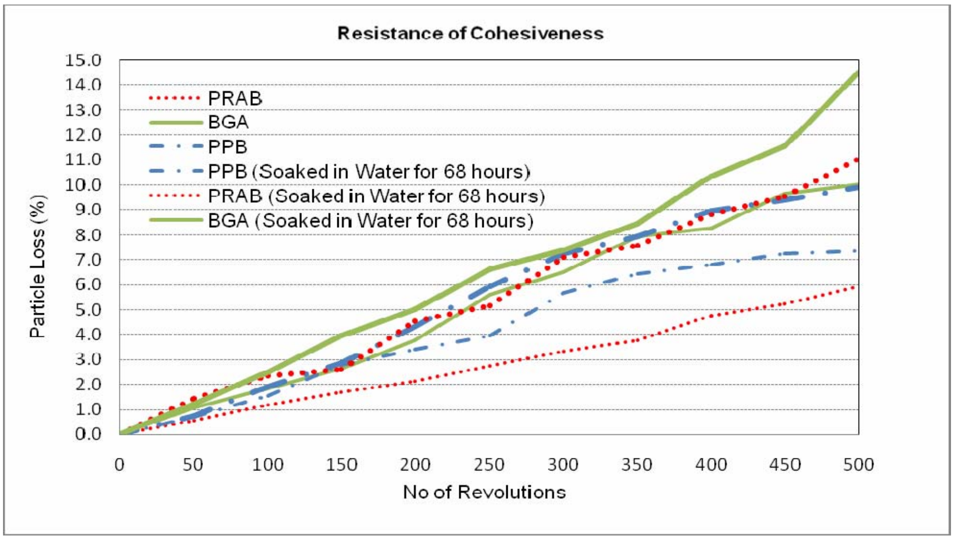

Figure 8 : Plot of dry and wet particle loss for AC mixes added BGA, using PRAB and using PPB

The trends indicate that for the same AC mix where the aggregate grading, bitumen content similar, the Wet Particle Loss Index of sample added BGA is less resistant to the effect of water than sample using PRAB or mixes using PPB 60/70 pen grade.

4.4 Fatigue properties of bituminous AC mixes added BGA, mixes using PRAB and mixes using PPB.

The type of bitumen used can have a strong influence on the fatigue performance of the bituminous mixes. Differences in bitumen type can lead to very large differences in fatigue life. In this research the method used for predicting fatigue life was the flexural tests on rectangular specimen tested as a simple supported beam using Beam Fatigue Testing.
The objective of this investigation was to examine the fatigue life of asphaltic concrete (AC) containing different type of bitumen, were added BGA, mixes using PRAB and mixes using PPB 60/70 pen grade.
Fatigue testing was applied to the various specimens at optimum bitumen content until the flexural modulus reach 50% of initial flexural modulus. For each set of specimens the magnitude of the target strain level was varied from a high to a small stress. The test was performed at a temperature of 20 °C with a Poission's ratio value of 0.40. The fatigue life for those mixes are plotted in Figure 9.

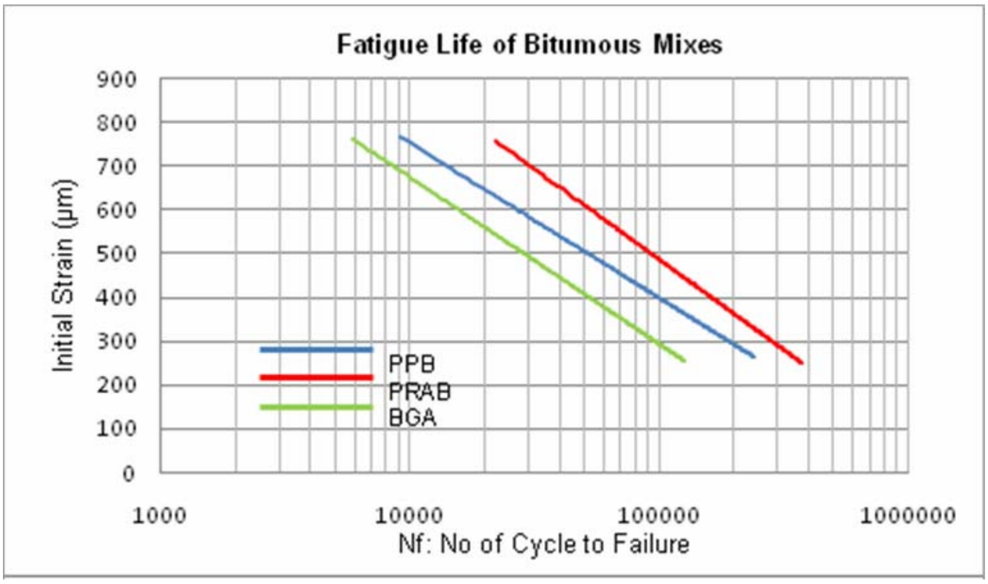

Figure 9 : Plot of trend fatigue's line of mixes added BGA, mixes using PRAB and mixes using PPB.

In terms of initial maximum strain the fatigue test results show that the addition of BGA to AC mixes, would be shorter than mixes using PRAB or mixes using PPB 60/70 pen grade as shown in Figure 9. This could be due in reality the bitumen from BGA not active as binder in the mixes so that the mixes is stiffer than other mixes. Meanwhile the fatigue life of mixes using PRAB is longer than mixes using PPB 60/70 pen grade, it could be due to the pure refinery bitumen asbuton (PRAB) is softer than petroleum bitumen pen 60/70 as indicated by its penetration value, so that the stiffness modulus of the mixes is lower than mixes using pure petroleum bitumen, as indicated by test results.

5. DETERMINING OF OPTIMUM QUANTITATIVE PERFORMANCE OF BITUMINOUS MIXES USING ASBUTON.

Due to the complexity of bituminous mixture, performance may not be predicted by a single variable. Choice must be a compromise of different properties. Therefore, it is necessary to examine the connection between mix variables to determine optimum properties. It has been found that the addition of BGA in the mixes will decrease some test properties and increases others. For example the addition of BGA in the mixes will be detrimental to the cohesiveness, stripping and fatigue life of the mixes in

term of control strain, but will improve deformation resistance, mix stiffness and so its increase load spreading ability.
Other factors that must be considered are pavement temperature and traffic loading. The data shows that mixes added by BGA is more resistant to temperature, as indicated by its stiffness modulus value is less temperature susceptible than mixes using pure refined bitumen asbuton (PRAB) or pure petroleum bitumen pen 60/70 (PPB), as shown in Figure 6.
The data shows that mixes containing BGA more appropriate for high temperatures. Traffic loading causes tensile stress and tensile strain in the bituminous pavement, and it depends on loading and properties of the pavements. In terms of initial strain level the fatigue test results indicate that mixes added BGA more appropriate for low volume traffic.

6. CONCLUSION

Based on the investigation conducted, the following conclusion are made:

1. Bitumen is only a minor component of bituminous mixes, but it has a crucial part to play in providing visco – elasticity and acting as a durable binder.
2. The refining process reduces the mineral content to produce Refined Asphalt Buton that has a bitumen content more than > 98 %. This new type possess high consistency and homogeneity allow a uniform high quality asphalt to be produced.
3. The addition of BGA has a significant effect on improving the mix stiffness
4. The presence of BGA 5% in the mixes, has a significant effect on resistance to permanent deformation, less temperature susceptible to stiffness modulus of bituminous mixes, and more appropriate for countries with a hot climate.
5. The addition of BGA 5% in the mixes decrease the cohesiveness , more than twice than mixes using pure petroleum bitumen pen grade 60/70 and mixes using pure refinery asbuton bitumen.
6. Bituminous mixes containing Buton Granular Asphlat (BGA) is less resistant to the effect of water than sample using pure refined bitumen asbuton or pure petroleum bitumen.
7. The addition of BGA in the mix has a significant effect on decreasing the fatigue performance in terms of initial maximum strain compare to the fatigue performance of mixes using pure petroleum bitumen or pure refinery asbuton bitumen.
8. The fatigue performance of mixes using pure refinery asbuton bitumen is little bit longer than mixes using pure petroleum bitumen 60/70 pen grade in term of strain level.
9. The choice of mixes using blend of BGA and petroleum bitumen should be a compromise selected to balance all of the mix properties requirement of a specific project. It is dependent on traffic load, strength of the existing pavement and climate conditions.
10. Development of Refined asbuton will enhance Indonesian ability to self – supply of the domestic bitumen demand and generate export

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